Chapter 6. Demersal Fishes and Megabenthic Invertebrates

INTRODUCTION

Marine fishes and invertebrates are conspicuous members of continental shelf habitats, and assessment of their communities has become an important focus of ocean monitoring programs throughout the world. Assemblages of bottom dwelling (demersal) fishes and relatively large (megabenthic), mobile invertebrates that live on the surface of the seafloor have been sampled extensively for more than 30 years on the mainland shelf of the Southern California Bight (SCB), primarily by programs associated with municipal wastewater and power plant discharges (Cross and Allen 1993). More than 100 species of demersal fishes inhabit the SCB, while the megabenthic invertebrate fauna consists of more than 200 species (Allen 1982, Allen et al. 1998, 2002, 2007). For the region surrounding the South Bay Ocean Outfall (SBOO), the most common trawl-caught fishes include speckled sanddab, longfin sanddab, hornyhead turbot, California halibut, and California lizardfish. Common trawl-caught invertebrates include various echinoderms (e.g., sea stars, sea urchins, sea cucumbers, sand dollars), crustaceans (e.g., crabs, shrimp), molluscs (e.g., marine snails, octopuses), and other taxa.

Demersal fish and megabenthic invertebrate communities are inherently variable and may be influenced by both anthropogenic and natural factors. These organisms live in close proximity to the seafloor and are therefore exposed to contaminants of anthropogenic origin that may accumulate in the sediments via deposition from both point and non-point sources (e.g., discharges from ocean outfalls and storm drains, surface runoff from watersheds, outflows from rivers and bays, disposal of dredge materials). Natural factors that may affect these organisms include prey availability (Cross et al. 1985), bottom relief and sediment structure (Helvey and Smith 1985), and changes in water temperatures associated with large scale oceanographic events such as El Niño/La Niña oscillations (Karinen et al. 1985). These factors can affect migration patterns of adult fish or the recruitment of juveniles into an area (Murawski 1993). Population fluctuations that affect species diversity and abundance of both fishes and invertebrates may also be due to the mobile nature of many species (e.g., fish schools, urchin aggregations).

The City of San Diego has been conducting trawl surveys in the area surrounding the SBOO since 1995. These surveys are designed to monitor the effects of wastewater discharge on the local marine biota by assessing the structure and stability of the trawl-caught fish and invertebrate communities. This chapter presents analyses and interpretations of the data collected during the 2008 trawl surveys. A long-term analysis of changes in these communities from 1995 through 2008 is also presented.

Materials and Methods

Field Sampling

Trawl surveys were conducted at seven fixed monitoring stations around the SBOO during 2008 (Figure 6.1). These surveys were conducted during January (winter), April (spring), July (summer), and October (fall) for a total of 28 trawls during the year. These stations, designated SD15–SD21, are located along the 28-m depth contour, and encompass an area ranging from south of Point Loma, California (USA) to an area off Punta Bandera, Baja California (Mexico). During each survey a single trawl was performed at each station using a 7.6-m Marinovich otter trawl fitted with a 1.3-cm cod-end mesh net. The net was towed for 10 minutes bottom time at a speed of about 2.5 knots along a predetermined heading.

Each trawl catch was brought on board for sorting and inspection. All fish and invertebrates captured were identified to species or to the lowest taxon possible. If an animal could not be identified in the field, it was returned to the laboratory for

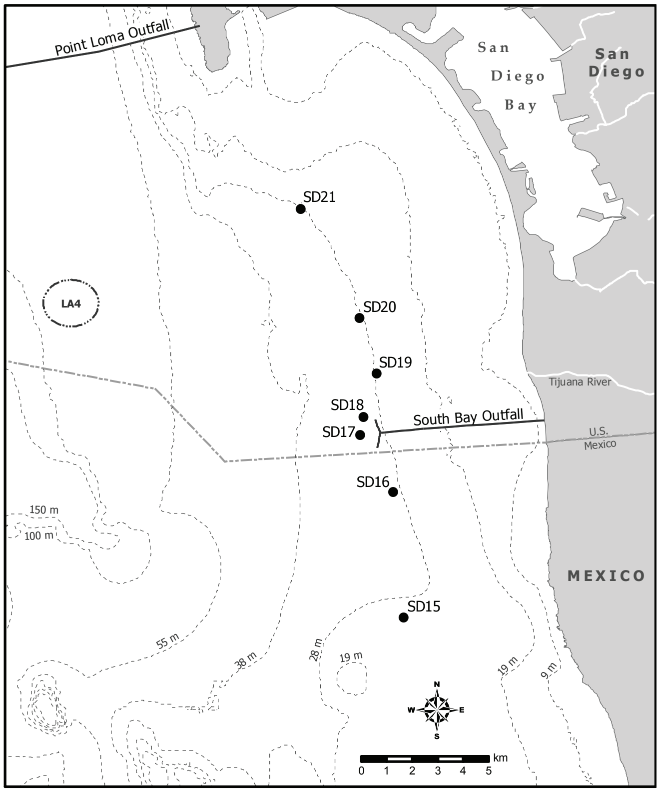

Figure 6.1
Otter trawl station locations, South Bay Ocean Outfall Monitoring Program.

further identification. For fishes, the total number of individuals and total biomass (kg, wet weight) were recorded for each species. Additionally, each individual fish was inspected for physical anomalies or indicators of disease (e.g., tumors, fin erosion, discoloration) as well as the presence of external parasites, and then measured to the nearest centimeter size class (standard lengths). For invertebrates, the total number of individuals was recorded per species. Due to the small size of most organisms, invertebrate biomass was typically measured as a composite weight of all species combined; however, large or exceptionally abundant species were weighed separately.

Data Analyses

Populations of each fish and invertebrate species were summarized as percent abundance, frequency of occurrence, mean abundance per haul, and mean abundance per occurrence. In addition, species richness (number of species), total abundance, total biomass, and Shannon diversity index (H') were calculated for each station. For historical comparisons, the data were grouped as “nearfield” stations (SD17, SD18), “south farfield” stations (SD15, SD16), and “north farfield” stations (SD19, SD20, SD21). The two nearfield stations were those located closest to the outfall (i.e., within 1000 m of the north or south diffuser legs).

A long-term multivariate analysis of demersal fish communities in the region was performed using data collected from 1995 through 2008. However, in order to eliminate noise due to natural seasonal variation in populations, this analysis was limited to data for the July surveys only over these 14 years. PRIMER software was used to examine spatio-temporal patterns in the overall similarity of fish assemblages in the region (see Clarke 1993, Warwick 1993, Clarke and Gorley 2006). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group-average linking, and ordination by non-metric multidimensional scaling (MDS). The fish abundance data were square root transformed and the Bray-Curtis measure of similarity was used as the basis for classification. Because species composition was sparse at some stations, a “dummy” species with a value of one was added to all samples prior to computing similarities (see Clarke and Gorley 2006). SIMPER analysis was subsequently used to identify the individual species that distinguished each cluster group.

Results and Discussion

Fish Community

Thirty-six species of fish were collected in the area surrounding the SBOO in 2008 (Table 6.1, Appendix E.1). The total catch for the year was 6221 individuals, representing an average of about 222 fish per trawl. Speckled sanddabs were the dominant fish captured, occurring in every haul and accounting for 59% of the total number of fishes collected during the year. Overall, this species averaged 131 fish per trawl, while all other species averaged less than 25 per haul. No other species contributed more

Table 6.1

Demersal fish species collected in 28 trawls in the SBOO region during 2008. PA=percent abundance; FO=frequency of occurrence; MAH=mean abundance per haul; MAO=mean abundance per occurrence.

Species	PA	FO	MAH	MAO	Species	PA	FO	MAH	MAO
Speckled sanddab	59	100	131	131	Kelp pipefish	<1	11	<1	2
Roughback sculpin	10	93	23	24	Pink seaperch	<1	11	<1	1
Yellowchin sculpin	8	71	19	26	Bigmouth sole	<1	7	<1	2
Pacific pompano	8	4	17	485	Pacific sanddab	<1	7	<1	1
California lizardfish	3	89	6	7	Pygmy poacher	<1	7	<1	1
Longfin sanddab	2	75	5	7	Shiner perch	<1	7	<1	1
Hornyhead turbot	2	96	4	5	Shovelnose guitarfish	<1	7	<1	1
Longspine combfish	2	54	4	8	Queenfish	<1	4	<1	10
Yellowfin croaker	2	4	4	98	Curlfin sole	<1	4	<1	2
English sole	1	71	3	4	Barred sand bass	<1	4	<1	1
California tonguefish	1	61	1	2	Calico rockfish	<1	4	<1	1
California scorpionfish	<1	43	1	2	Deepwater blenny	<1	4	<1	1
California halibut	<1	36	1	1	Giant kelpfish	<1	4	<1	1
Plainfin midshipman	<1	32	1	3	Round stingray	<1	4	<1	1
Specklefin midshipman	<1	25	1	3	Sarcastic fringehead	<1	4	<1	1
Fantail sole	<1	25	<1	1	Slimy snailfish	<1	4	<1	1
Spotted turbot	<1	18	<1	1	Spotted cuskeel	<1	4	<1	1
California skate	<1	18	<1	1	Thornback	<1	4	<1	1

than 10% of the total catch. Only roughback sculpin, yellowchin sculpin, California lizardfish, longfin sanddab, hornyhead turbot, longspine combfish, English sole, and California tonguefish occurred in at least 50% of the trawls. Additionally, an unusually large number of Pacific pompano (485 fish) was collected in a single trawl from station SD21 during the October 2008 survey (see Appendix E.2). The majority of species captured in the South Bay region tended to be relatively small fish with an average length <20 cm (see Appendix E.1). Although larger species such as the California skate, shovelnose guitarfish, thornback and round stingray were also captured during the year, these skates and rays were relatively rare compared to the bony fishes.

During 2008, species richness (number of species) and diversity (H') values for the South Bay fish assemblages were relatively low compared to other areas of the SCB (e.g., Allen et al. 1998, 2002, 2007), while abundance and biomass values varied widely in the region (Table 6.2). No more than 16 species occurred in any one haul, and the corresponding H' values were all less than 2.0. As in previous years, trawls from station SD15 located the farthest south in Mexican waters had the lowest average species richness (7 species) and diversity (H'=0.51) values of all sites. Total abundance ranged from 35 to 628 fishes per haul over all stations, which generally co-varied with speckled sanddab populations that ranged from 7 to 265 fish per catch (see Appendix E.2). The main exception to this trend was the extremely large haul at station SD21 in October that contained large numbers of Pacific pompano (see above), as well as almost 100 yellowfin croaker, but only seven speckled sanddabs. Biomass varied widely from 0.8 to 17.3 kg per haul, with higher biomass values coincident with greater numbers of fishes as expected (Appendix E.3). As with species richness and diversity, the lowest values for total abundance and biomass tended to occur at station SD15.

Although average species richness values for SBOO demersal fish assemblages have remained within a narrow range over the years (i.e., 5–14 species/station/year), the average abundance per haul has fluctuated greatly (i.e., 28–302 fish/station/year) mostly in response to population fluctuations of a few dominant species (see Figures 6.2 and 6.3). For example, the increase in average total abundance per

Table 6.2

Summary of demersal fish community parameters for SBOO stations sampled during 2008. Data are included for species richness (number of species), abundance (number of individuals), diversity (H'), and biomass (kg, wet weight).

Station	Jan	Apr	Jul	Oct	Annual Mean	Annual SD	Station	Jan	Apr	Jul	Oct	Annual Mean	Annual SD
Species richness							*Abundance*						
SD15	5	11	7	6	7	3	SD15	66	200	67	35	92	74
SD16	9	13	9	8	10	2	SD16	332	371	181	72	239	138
SD17	14	10	8	12	11	3	SD17	216	291	230	121	215	70
SD18	10	13	8	9	10	2	SD18	269	286	119	97	193	99
SD19	8	12	12	7	10	3	SD19	282	351	263	191	272	66
SD20	9	8	13	10	10	2	SD20	282	341	249	102	244	102
SD21	12	12	16	12	13	2	SD21	165	270	144	628	302	224
Survey Mean	10	11	10	9			Survey Mean	230	301	179	178		
Survey SD	3	2	3	2			Survey SD	90	58	73	204		
Diversity							*Biomass*						
SD15	0.33	0.56	0.44	0.72	0.51	0.17	SD15	1.3	4.8	4.1	0.8	2.7	2.0
SD16	0.45	1.23	0.61	0.94	0.81	0.35	SD16	3.6	5.2	3.5	2.2	3.6	1.2
SD17	1.39	1.51	1.02	1.27	1.30	0.21	SD17	7.7	4.2	3.8	5.9	5.4	1.8
SD18	1.41	1.61	0.98	1.13	1.28	0.28	SD18	6.0	5.4	2.9	4.5	4.7	1.3
SD19	0.90	1.03	1.00	1.11	1.01	0.09	SD19	3.6	5.5	7.4	2.4	4.7	2.2
SD20	1.17	1.59	1.28	1.28	1.33	0.18	SD20	3.9	4.3	5.3	1.9	3.8	1.4
SD21	1.34	1.77	1.27	1.04	1.36	0.30	SD21	6.5	4.3	6.7	17.3	8.7	5.8
Survey Mean	1.00	1.33	0.94	1.07			Survey Mean	4.7	4.8	4.8	5.0		
Survey SD	0.45	0.42	0.32	0.20			Survey SD	2.2	0.6	1.7	5.7		

station that occurred between 2006 and 2008 at stations SD16, SD19, and SD20 (Figure 6.2), reflects a similar pattern in speckled sanddab populations alone (Figure 6.3). This trend reverses the substantial drop in the speckled sanddab catches that occurred from 2004 to 2006. Trawl catches of roughback sculpin and yellowchin sculpin were also greater in 2008 than in previous years at several stations. Whereas population fluctuations of common species such as speckled sanddab, roughback, and yellowchin sculpin tend to occur across the entire study area, intra-station variability is most often associated with large hauls of schooling species that occur infrequently. For example, large hauls of white croaker were responsible for the high abundance at station SD21 in 1996, a large haul of northern anchovy caused the relatively high abundance at station SD16 in 2001, and the 2008 annual mean for station SD21 reflects the large haul of Pacific pompano discussed previously. Overall, none of the observed changes appear to be associated with wastewater discharge via the SBOO.

Classification analyses of long-term data (1995–2008, July surveys only) discriminated between seven main types of fish assemblages (cluster groups A–G) in the South Bay region (Figure 6.4). These assemblages can be distinguished by differences in the relative abundances of the common species that were present, although most were dominated by speckled sanddabs. The distribution of assemblages in 2008 was generally similar to that seen in previous years, especially between 2003–2007, and no patterns appear to be associated with proximity to the outfall. Instead, most differences seem to be more closely related to large-scale oceanographic events (e.g., El Niño conditions in 1998) or the unique characteristics of a specific station location. For example, station SD15 located far south of the outfall in Mexican waters off northern Baja California often grouped apart from the remaining

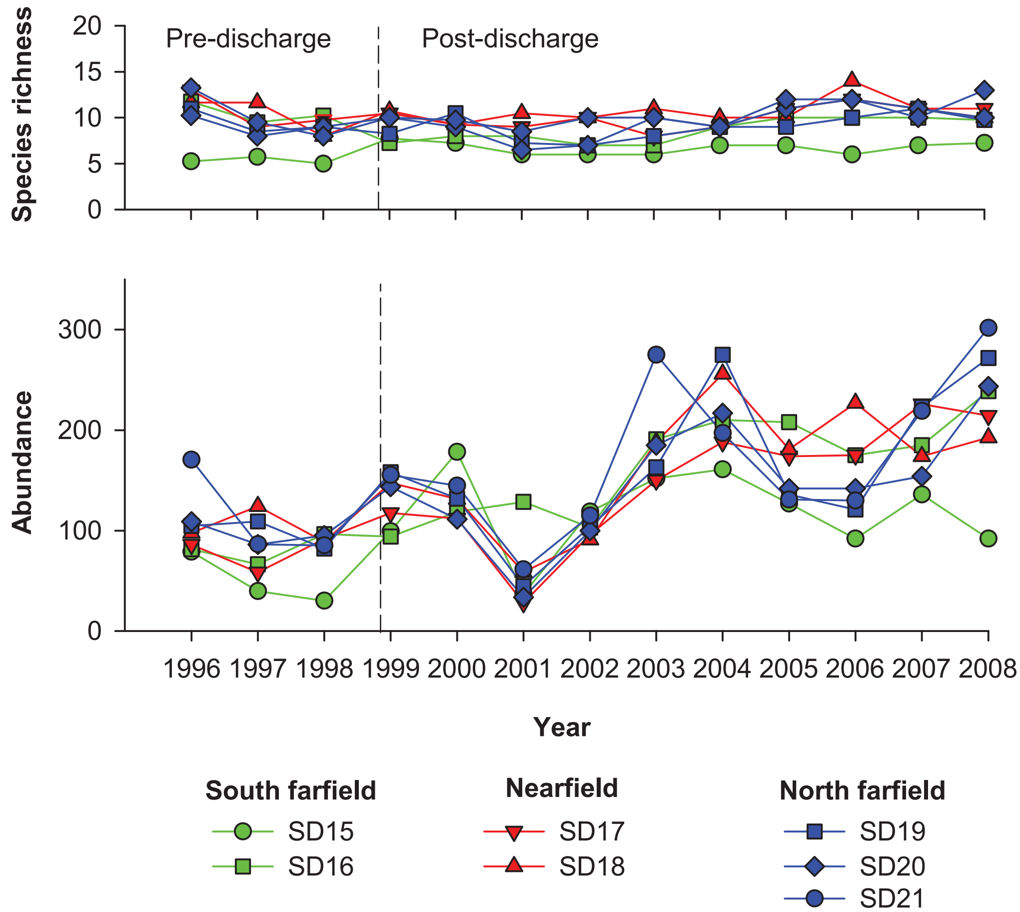

Figure 6.2
Species richness (number of species) and abundance (number of individuals) of demersal fish collected at each SBOO trawl station from 1996 through 2008. Data are annual means (n=4). Dotted line represents initiation of wastewater discharge.

stations. The composition and main characteristics of each cluster group are described below (Table 6.3, Appendix E.4).

Cluster group A represented the fish assemblages present only at stations SD16 and SD17 sampled in July 2006 (Figure 6.4). This group was unique in that it was characterized by more than 200 California lizardfish per haul, which was more than an order of magnitude greater for this species than in any other cluster group (Table 6.3). The second and third most abundant species comprising this group were the speckled sanddab (~56 fish/haul) and yellowchin sculpin (~15 fish/haul). The relative abundance of these three species distinguished this cluster group from all others (Appendix E.4).

Cluster group B was the third largest group and represented assemblages from 11 of the 14 station-surveys during 1995–1996 (i.e., representing all seven sites) and one or two stations each during 1997 (SD19, SD21), 1999 (SD17, SD21), 2000 (SD20, SD21), 2001 (SD21), and 2002 (SD18, SD21) (Figure 6.4). This group also represented assemblages from a few hauls at SD21 in 2005–2006, and a single haul at SD18 in 2008. Similar to most other groups, the dominant species was the speckled sanddab (~62 fish/haul) (Table 6.3). Group B was also characterized by the greatest number of hornyhead turbots on average and had twice as many longfin sanddabs (~23 fish/haul) as in the other groups. The relative abundance of speckled and longfin sanddabs, as well as California tonguefish, yellowchin sculpin, California lizardfish and hornyhead turbot, distinguished this assemblage from the other cluster groups (Appendix E.4).

Cluster group C was the second largest group and comprised assemblages that occurred at a mix of

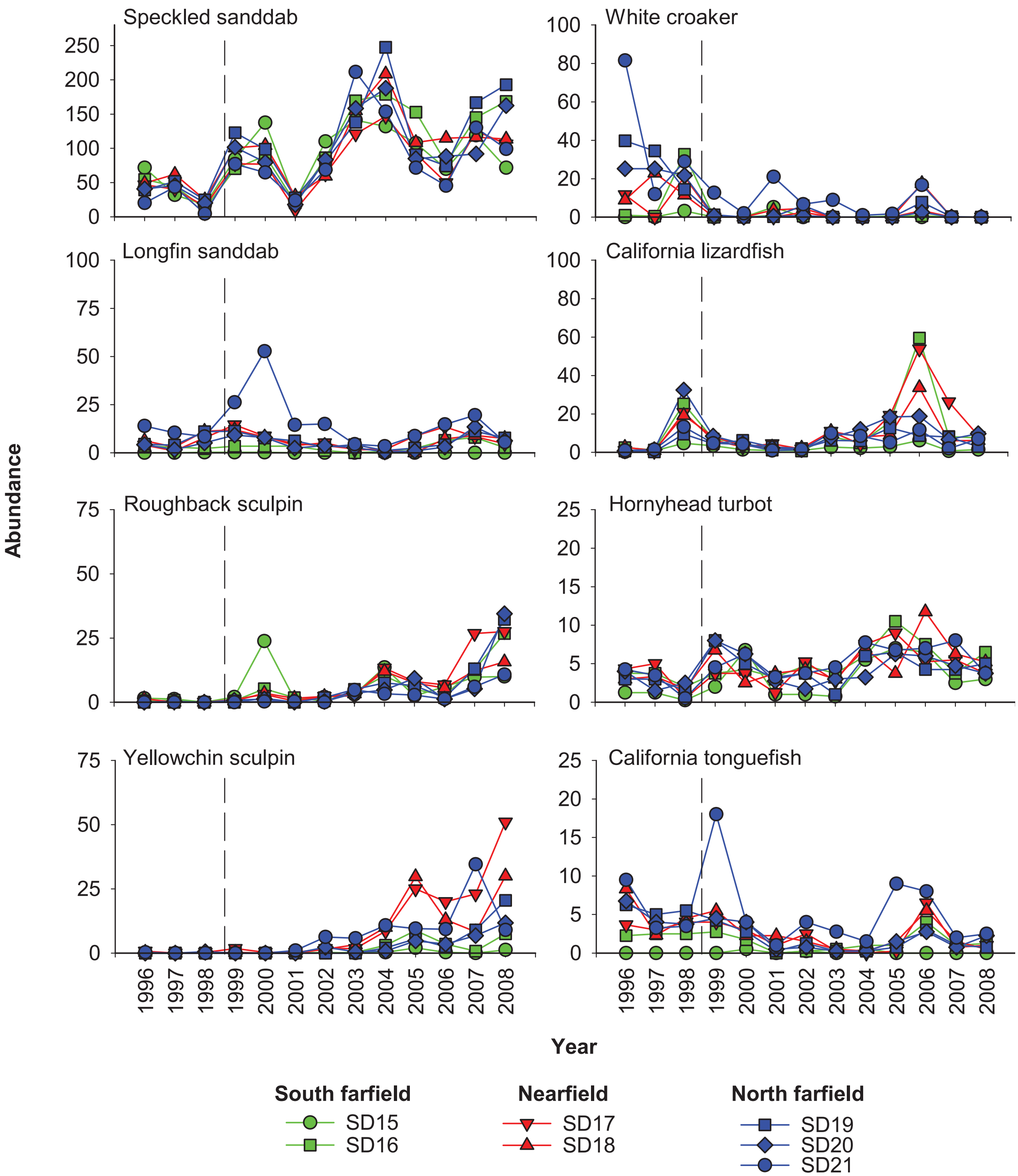

Figure 6.3
Abundance of the eight most abundant fish species collected in the SBOO region from 1996 through 2008. Data are annual means per station (n=4). Dotted line represents initiation of wastewater discharge.

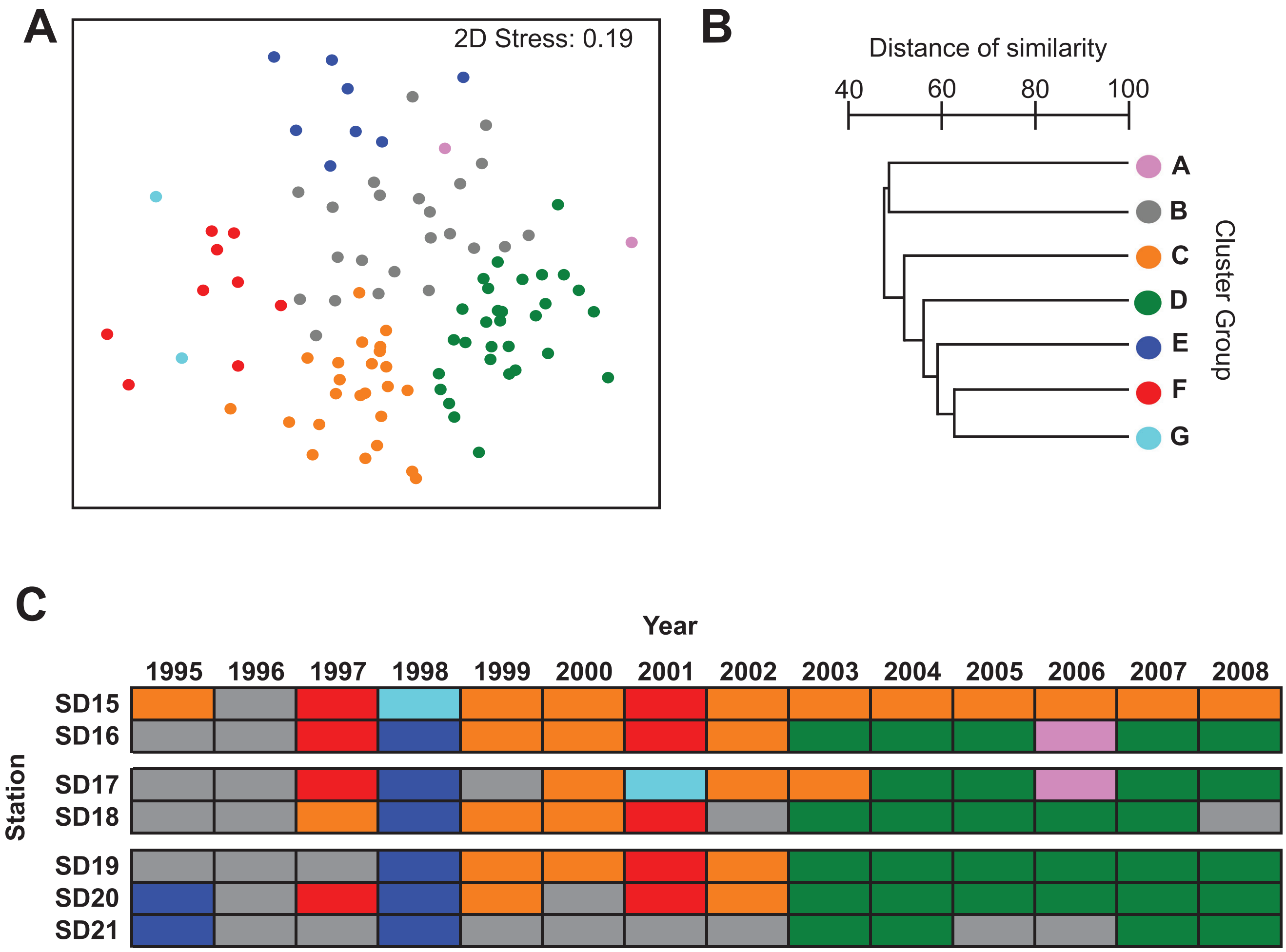

Figure 6.4
Results of classification analysis of demersal fish assemblages collected at SBOO stations SD15–SD21 between 1995 and 2008 (July surveys only). Data are presented as (A) MDS ordination, (B) a dendrogram of major cluster groups, and (C) a matrix showing distribution of cluster groups over time.

sites sampled during all years except 1996, 1998, and 2001. This included station SD15 in 10 out of 14 surveys and a majority of the other stations sampled during 1999, 2000, and 2002 (Figure 6.4). Group C was characterized by the second highest average abundance of speckled sanddabs (~105 fish/haul) and very few other species (Table 6.3). This group differed from most others in the relative abundance of not only speckled sanddabs, but also longfin sanddabs, California lizardfish, and hornyhead turbot (Appendix E.4). In addition, fewer numbers of yellowchin and roughback sculpin distinguished group C from cluster group D.

Cluster group D represented the assemblages from about 71% of the trawls performed from 2003 through 2008 (Figure 6.4). Assemblages represented by this group were characterized by having the highest number of speckled sanddabs (~152 fish/haul; Table 6.3), and were also distinguished from the other cluster groups by relatively high numbers of yellowchin sculpin, roughback sculpin, and California lizardfish (Appendix E.4). The larger hauls of speckled sanddabs that started to occur in 1999 (e.g., represented by cluster group C) versus previous years (e.g., represented by cluster groups B, E, and F), and that continued to increase over the time period represented by group D coincide with colder water conditions associated with oceanographic events such as La Niña (see Chapter 2).

Cluster group E comprised assemblages from the two northernmost stations (SD20, SD21) sampled in 1995, as well as from every station except SD15

Table 6.3

Description of cluster groups A–G defined in Figure 6.4. Data include number of hauls, mean species richness, mean total abundance, and mean abundance of the five most abundant species for each station group. Values that are underlined indicate species that were considered "characteristic" of that group according to SIMPER analyses (i.e., similarity/standard deviation ≥2.0).

	Group A	Group B	Group C	Group D	Group E	Group F	Group G
Number of hauls	2	23	24	30	8	9	2
Mean species richness	8	10	6	10	9	7	6
Mean abundance	299	117	117	218	64	38	28
Species				**Mean Abundance**			
California lizardfish	212	4	3	13	24	1	8
Speckled sanddab	56	<u>62</u>	<u>105</u>	<u>152</u>	<u>12</u>	<u>25</u>	15
Yellowchin sculpin	15	4	<1	20	1	—	—
Longfin sanddab	5	23	<1	7	<u>12</u>	<1	1
Hornyhead turbot	4	<u>6</u>	3	4	<u>3</u>	4	1
Roughback sculpin	3	<1	<1	9	—	—	—
California tonguefish	3	5	1	1	2	1	—
English sole	2	3	<1	3	5	<1	—
California scorpionfish	1	1	1	1	<1	2	2
Fantail sole	—	1	<1	<1	1	<1	1
Spotted turbot	—	1	2	1	1	3	1
California skate	—	—	<1	<1	<1	<1	1

sampled during warm water conditions associated with the 1998 El Niño (Figure 6.4). This group averaged about 64 individuals and 9 species per haul, and was characterized by the lowest abundance of speckled sanddabs (~12 fish/haul) (Table 6.3). The dominant species in this group was California lizardfish (~24 fish/haul) followed by longfin sanddabs (~12 fish/haul) and speckled sanddabs (as above); the relative abundance of these species distinguished this group from all of the others (Appendix E.4).

Cluster groups F and G comprised assemblages also sampled during warmer than normal ocean conditions (see Chapter 2). The fish assemblages represented by group F were collected at four stations sampled in July 1997 (i.e., southern stations SD15 and SD16, station SD17 near the outfall, northern station SD20) and every station except SD17 and SD21 during July 2001 (Figure 6.4). Assemblages represented by group G were from just two trawls, one from station SD15 in 1998 and one from stations SD17 in 2001. Overall, these groups averaged the fewest fish per haul (i.e., 38 fish/7 species for group F; 28 fish/6 species for group G), which reflected the small average number of speckled sanddabs in these two groups. Groups F and G were further distinguished from the other cluster groups by their relative (but usually lower) abundance of several common species, including longfin sanddab, yellowchin sculpin, California lizardfish, hornyhead turbot, roughback sculpin and English sole (Appendix E.4). Assemblages represented by group G differed from those represented by group F in the relative contribution of speckled sanddabs, California lizardfish, and hornyhead turbot.

Physical Abnormalities and Parasitism

Demersal fish populations appeared healthy in the SBOO region during 2008. There were no incidences of fin rot, discoloration, skin lesions, tumors, or any other physical abnormalities or indicators of disease among fishes collected during the year. Evidence of parasitism was also very low for trawl-caught fishes in the region. Only two external parasites were observed still attached to their host. These included a leech (Annelida, Hirudinea) attached to a hornyhead turbot at station SD17 in October, and the cymothoid isopod *Elthusa vulgaris* attached to

Table 6.4

Species of megabenthic invertebrates collected in 28 trawls in the SBOO region during 2008. PA=percent abundance; FO=frequency of occurrence; MAH=mean abundance per haul; MAO=mean abundance per occurrence.

Species	PA	FO	MAH	MAO	Species	PA	FO	MAH	MAO
Astropecten verrilli	51	93	13	14	*Aphrodita* sp	<1	4	<1	2
Dendraster terminalis	13	18	3	18	*Crangon alaskensis*	<1	4	<1	2
Crangon nigromaculata	9	39	2	6	*Dortyteuthis opalescens*	<1	4	<1	2
Pisaster brevispinus	4	50	1	2	*Lovenia cordiformis*	<1	4	<1	2
Lytechinus pictus	3	18	1	4	*Pandalus platyceros*	<1	4	<1	2
Hemisquilla californiensis	2	29	1	2	*Armina californica*	<1	4	<1	1
Heterocrypta occidentalis	2	18	<1	3	*Calliostoma canaliculatum*	<1	4	<1	1
Octopus rubescens	1	14	<1	3	*Calliostoma gloriosum*	<1	4	<1	1
Acanthodoris brunnea	1	11	<1	3	*Crangon alba*	<1	4	<1	1
Pyromaia tuberculata	1	18	<1	1	*Dendronotus frondosus*	<1	4	<1	1
Elthusa vulgaris	1	14	<1	2	*Dendronotus iris*	<1	4	<1	1
Halosydna latior	1	18	<1	1	*Euspira lewisii*	<1	4	<1	1
Ophiothrix spiculata	1	14	<1	1	*Flabellina pricei*	<1	4	<1	1
Kelletia kelletii	1	11	<1	2	*Heptacarpus palpator*	<1	4	<1	1
Philine auriformis	1	11	<1	2	*Heptacarpus stimpsoni*	<1	4	<1	1
Metacarcinus gracilis	1	7	<1	3	*Loxorhynchus crispatus*	<1	4	<1	1
Randallia ornata	1	11	<1	1	*Loxorhynchus* sp	<1	4	<1	1
Romaleon antennarius	1	7	<1	2	*Megastraea turbanica*	<1	4	<1	1
Luidia armata	<1	11	<1	1	*Paguristes ulreyi*	<1	4	<1	1
Platymera gaudichaudii	<1	11	<1	1	*Panulirus interruptus*	<1	4	<1	1
Pugettia producta	<1	4	<1	3	*Pinnixa franciscana*	<1	4	<1	1
Metacarcinus anthonyi	<1	7	<1	1	*Podochela hemphillii*	<1	4	<1	1
Crossata californica	<1	7	<1	1	*Pugettia richii*	<1	4	<1	1
Flabellina iodinea	<1	7	<1	1	*Sicyonia ingentis*	<1	4	<1	1
Loxorhynchus grandis	<1	7	<1	1	*Stylatula elongata*	<1	4	<1	1
Pagurus spilocarpus	<1	7	<1	1	*Thesea* sp B	<1	4	<1	1
Pandalus danae	<1	7	<1	1	*Tritonia diomedea*	<1	4	<1	1

a spotted turbot at station SD18 in July. In addition to the specimen identified on the spotted turbot, six other *E. vulgaris* were identified as part of the trawl catch throughout the year (see Appendix E.5). Since cymothoids often become detached from their hosts during retrieval and sorting of the trawl catch, it is unknown which fishes were actually parasitized by these isopods. However, *E. vulgaris* is known to be especially common on sanddabs and California lizardfish in southern California waters, where it may reach infestation rates of 3% and 80%, respectively (see Brusca 1978, 1981).

Invertebrate Community

A total of 698 megabenthic invertebrates (~25 per trawl), representing 54 taxa, were collected during 2008 (Table 6.4, Appendix E.5). As in previous years, the asteroid *Astropecten verrilli* was the most abundant and most frequently captured species. This sea star was captured in 93% of the trawls and accounted for 51% of the total invertebrate abundance. Another sea star, *Pisaster brevispinus*, occurred in 50% of the trawls but accounted for only 4% of the total abundance. The remaining taxa occurred infrequently, with only two species occurring in 20% or more of the hauls. With the exception of *A. verrilli*, all of the species collected averaged no more than three individuals per haul.

Megabenthic invertebrate community structure varied among stations and between surveys during the year (Table 6.5). Species richness ranged from 1 to 12 species per haul, diversity (H') values ranged from 0 to 2.11 per haul, and total abundance ranged from 3 to 144 individuals per haul. The biggest hauls

Table 6.5

Summary of megabenthic invertebrate community parameters for SBOO stations sampled during 2008. Data are included for species richness (number of species), abundance (number of individuals), diversity (H'), and biomass (kg, wet weight).

					Annual							Annual	
Station	**Jan**	**Apr**	**Jul**	**Oct**	**Mean**	**SD**	**Station**	**Jan**	**Apr**	**Jul**	**Oct**	**Mean**	**SD**
Species richness							*Abundance*						
SD15	4	5	6	6	5	1	SD15	13	144	90	65	78	54
SD16	7	4	3	4	5	2	SD16	23	10	7	21	15	8
SD17	6	3	9	12	8	4	SD17	17	3	14	28	16	10
SD18	5	1	9	12	7	5	SD18	14	6	21	46	22	17
SD19	3	3	4	5	4	1	SD19	21	6	10	19	14	7
SD20	4	8	3	7	6	2	SD20	19	16	7	11	13	5
SD21	5	5	9	6	6	2	SD21	18	12	20	17	17	3
SurveyMean	5	4	6	7			SurveyMean	18	28	24	30		
Survey SD	1	2	3	3			Survey SD	4	51	30	19		
Diversity							*Biomass*						
SD15	0.79	0.84	0.54	0.51	0.67	0.17	SD15	0.6	0.5	0.3	0.3	0.4	0.1
SD16	1.33	1.19	0.96	0.57	1.01	0.33	SD16	0.8	0.1	0.3	0.3	0.4	0.3
SD17	1.50	1.10	2.11	1.86	1.64	0.44	SD17	1.2	0.2	1.1	0.2	0.7	0.5
SD18	1.48	0.00	1.80	2.11	1.35	0.94	SD18	1.4	0.1	0.5	0.1	0.5	0.6
SD19	0.85	0.87	1.17	1.02	0.97	0.15	SD19	0.1	0.7	0.5	0.1	0.3	0.3
SD20	1.03	1.77	0.80	1.85	1.36	0.53	SD20	0.5	1.6	0.1	2.0	1.0	0.9
SD21	1.38	1.23	2.02	1.50	1.53	0.34	SD21	0.7	0.4	1.4	0.6	0.8	0.4
SurveyMean	1.19	1.00	1.34	1.34			SurveyMean	0.8	0.5	0.6	0.5		
Survey SD	0.30	0.54	0.63	0.65			Survey SD	0.4	0.5	0.5	0.7		

all occurred at station SD15 and were characterized by large numbers of *A. verrilli* (Appendix E.6). Although biomass was also somewhat variable (0.1–1.60 kg), the highest values generally corresponded to the collection of relatively large sea stars or crabs.

Variations in megabenthic invertebrate community structure in the South Bay region generally reflect changes in species abundance (Figures 6.5, 6.6). Although species richness has varied little over the years (e.g., 4–14 species/trawl), annual abundance values have averaged between 7 and 273 individuals per haul. These large differences have typically been due to fluctuations in populations of several dominant species, including especially *A. verrilli*, the sea urchin *Lytechinus pictus*, the sand dollar *Dendraster terminalis,* and the shrimp *Crangon nigromaculata* (Figure 6.6). For example, trawls at station SD15 have had the highest average abundance compared to the other stations for 8 out of 14 years due to relatively large populations of *A. verrilli*, *L. pictus,* and *D. terminalis*. In addition, the high abundances recorded at station SD17 in 1996 were due to large hauls of *L. pictus*. None of the observed variability in the invertebrate communities appears to be related to the South Bay outfall.

Summary and Conclusions

As in previous years, speckled sanddabs continued to dominate fish assemblages surrounding the SBOO during 2008. This species occurred at all stations and accounted for 59% of the total catch. Other characteristic, but less abundant species included the roughback sculpin, yellowchin sculpin, California lizardfish, longfin sanddab, hornyhead turbot, longspine combfish, English sole, and California tonguefish. Most of these common fishes were relatively small, averaging less than 20 cm in length. Although the composition and structure of the fish assemblages varied among stations, these differences were mostly due to variations in speckled sanddab populations.

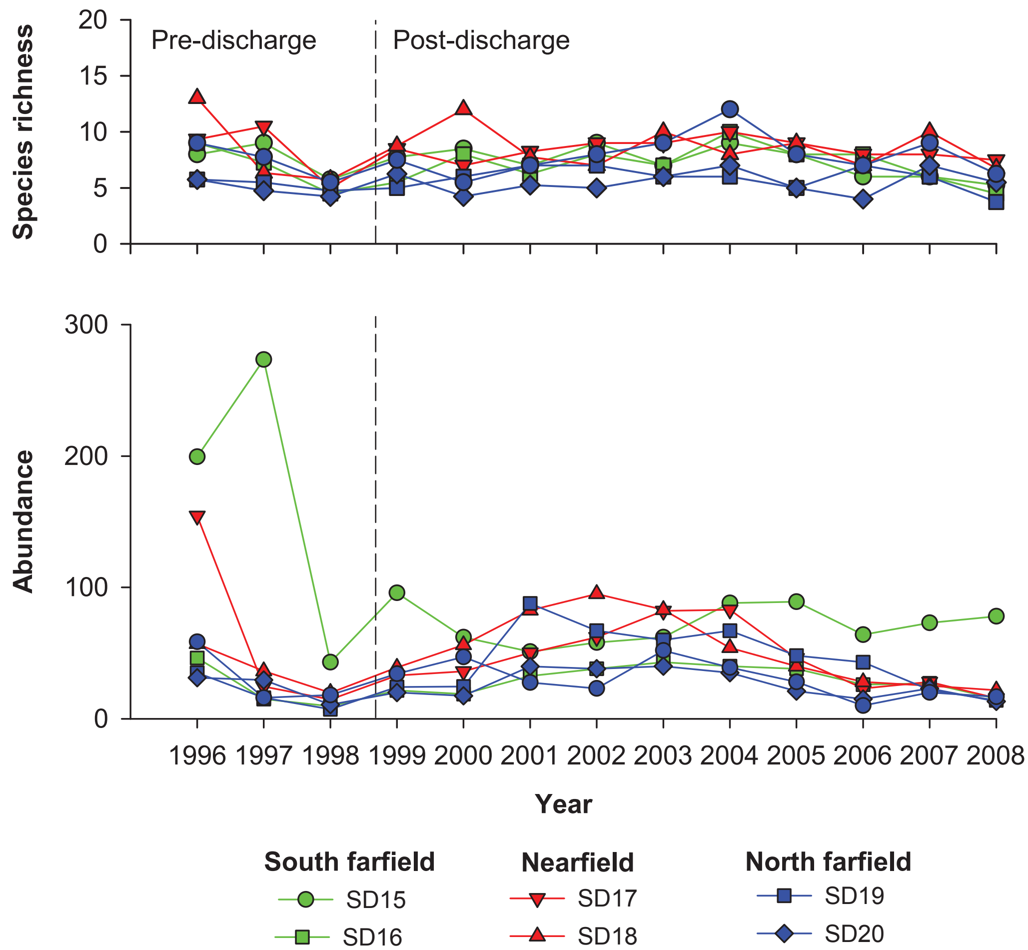

Figure 6.5

Species richness (number of species) and abundance (number of individuals) of megabenthic invertebrates collected in the SBOO region from 1996 through 2008. Data are annual means (n=4). Dotted line represents initiation of wastewater discharge.

Assemblages of relatively large (megabenthic) invertebrates in the region were similarly dominated by one prominent species, the sea star *Astropecten verrilli*. Variations in community structure of the trawl-caught invertebrates generally reflect changes in the abundance of this sea star, as well as other dominant species such as the urchin *Lytechinus pictus*, the sand dollar *Dendraster terminalis,* and the shrimp *Crangon nigromaculata.*

Overall, results of the 2008 trawl surveys provide no evidence that wastewater discharged through the SBOO has affected either demersal fish or megabenthic invertebrate communities in the region. Although highly variable, patterns in the abundance and distribution of species were similar at stations located near the outfall and farther away, with no discernable changes in the region following the onset of the SBOO wastewater discharge. Instead, the high degree of variability in these communities observed during 2008 was similar to those that occurred in previous years (e.g., City of San Diego 2006–2008), including the period before initiation of wastewater discharge (City of San Diego 2000). In addition, the low species richness and abundances of fish and invertebrates found during the 2008 surveys are consistent with what is expected for the relatively shallow, sandy habitats in which the SBOO stations are located (see Allen et al. 1998, 2002, 2007). Changes in these communities appear to be more likely due to natural factors such as changes in ocean water temperatures associated with large-scale oceanographic events (e.g., El Niño or La Niña) or to the mobile nature of many of the resident species collected. Finally, the

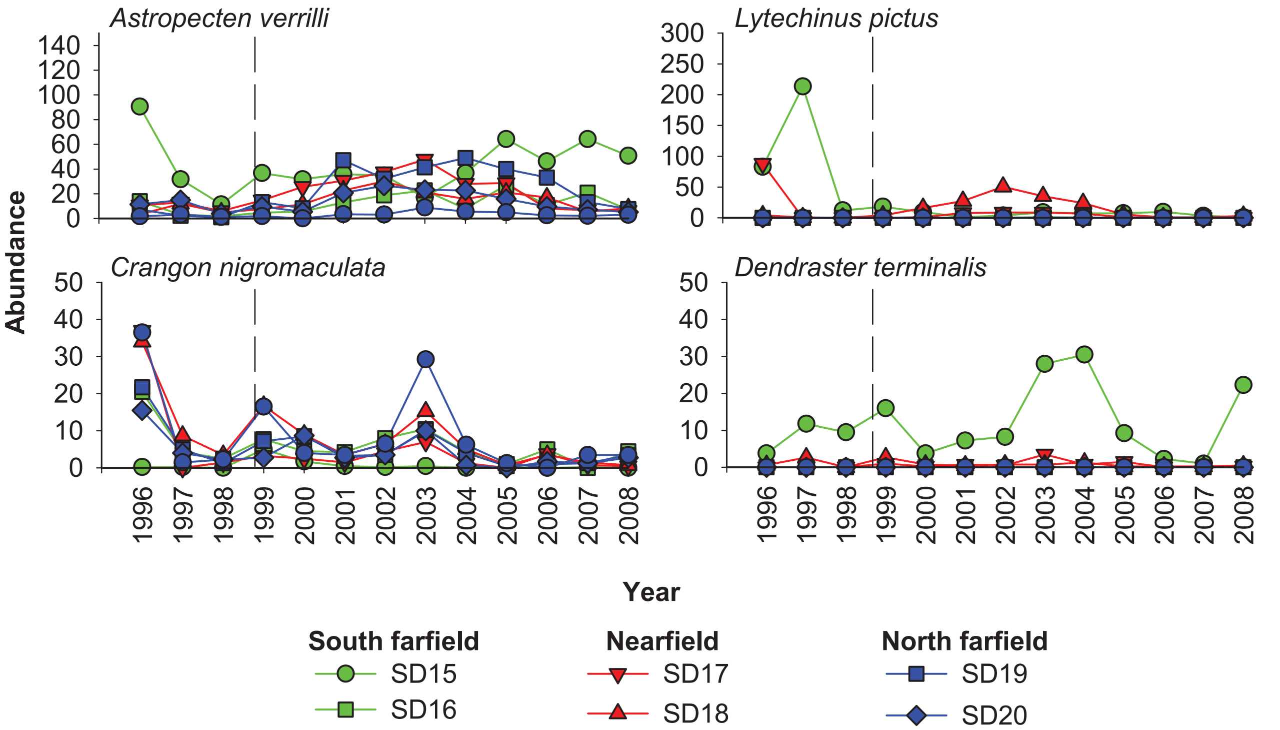

Figure 6.6
Abundance (number of individuals) of the four most abundant megabenthic species collected in the SBOO region from 1996 through 2008. Data are annual means (n=4). Dotted line represents initiation of wastewater discharge.

absence of disease or other physical abnormalities in local fishes suggests that populations in the area continue to be healthy.

Literature Cited

Allen, M.J. (1982). Functional structure of soft-bottom fish communities of the southern California shelf. Ph.D. dissertation. University of California, San Diego. La Jolla, CA.

Allen, M.J. (2005). The check list of trawl-caught fishes for Southern California from depths of 2–1000 m. Southern California Coastal Water Research Project, Westminister, CA.

Allen, M.J., S.L. Moore, K.C. Schiff, S.B. Weisberg, D. Diener, J.K. Stull, A. Groce, J. Mubarak, C.L. Tang, and R. Gartman. (1998). Southern California Bight 1994 Pilot Project: Chapter V. Demersal Fishes and Megabenthic Invertebrates. Southern California Coastal Water Research Project, Westminster, CA.

Allen, M.J., A.K. Groce, D. Diener, J. Brown, S.A. Steinert, G. Deets, J.A. Noblet, S.L. Moore, D. Diehl, E.T. Jarvis, V. Raco-Rands, C. Thomas, Y. Ralph, R. Gartman, D. Cadien, S.B. Weisberg, and T. Mikel. (2002). Southern California Bight 1998 Regional Monitoring Program: V. Demersal Fishes and Megabenthic Invertebrates. Southern California Coastal Water Research Project. Westminster, CA.

Allen, M.J., T. Mikel, D. Cadien, J.E. Kalman, E.T. Jarvis, K.C. Schiff, D.W. Diehl, S.L. Moore, S. Walther, G. Deets, C. Cash, S. Watts, D.J. Pondella II, V. Raco-Rands, C. Thomas, R. Gartman, L. Sabin, W. Power, A.K. Groce, and J.L. Armstrong. (2007). Southern California Bight 2003 Regional Monitoring Program: IV. Demersal Fishes and Megabenthic Invertebrates. Southern California Coastal Water Research Project. Costa Mesa, CA.

Brusca, R.C. (1978). Studies on the cymothoid fish symbionts of the eastern Pacific (Crustacea: Cymothoidae). II. Systematics and biology of *Livoneca vulgaris* Stimpson 1857. Occassional Papers of the Allan Hancock Foundation. (New Series), 2: 1–19.

Brusca, R.C. (1981). A monograph on the Isopoda Cymothoidae (Crustacea) of the eastern Pacific. Zoological Journal of the Linnean Society, 73: 117–199.

City of San Diego. (2000). International Wastewater Treatment Plant Final Baseline Ocean Monitoring Report for the South Bay Ocean Outfall (1995–1998). City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2006). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (South Bay Water Reclamation Plant), 2005. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2007). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (South Bay Water Reclamation Plant), 2006. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2008). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (South Bay Water Reclamation Plant), 2007. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Clarke, K.R. (1993). Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology, 18: 117–143.

Clarke, K.R. and R.N. Gorley. (2006). Primer v6: User Manual/Tutorial. PRIMER-E: Plymouth.

Cross, J.N., J.N. Roney, and G.S. Kleppel. (1985). Fish food habitats along a pollution gradient. California Fish and Game, 71: 28–39.

Cross, J.N. and L.G. Allen. (1993). Chapter 9. Fishes. In: Dailey, M.D., D.J. Reish, and J.W. Anderson (eds.). Ecology of the Southern California Bight: A Synthesis and Interpretation. University of California Press, Berkeley, CA. p 459–540.

Eschmeyer, W.N. and E.S. Herald. (1998). A Field Guide to Pacific Coast Fishes of North America. Houghton and Mifflin Company, New York.

Helvey, M. and R.W. Smith. (1985). Influence of habitat structure on the fish assemblages associated with two cooling-water intake structures in southern California. Bulletin of Marine Science, 37: 189–199.

Karinen, J.B., B.L. Wing, and R.R. Straty. (1985). Records and sightings of fish and invertebrates in the eastern Gulf of Alaska and oceanic phenomena related to the 1983 El Niño event. In: W.S. Wooster and D.L. Fluharty (eds.). El Niño North: El Niño Effects in the Eastern Subarctic Pacific Ocean. Washington Sea Grant Program. p 253–267.

Murawski, S.A. (1993). Climate change and marine fish distribution: forecasting from historical analogy. Transactions of the American Fisheries Society, 122: 647–658.

[SCAMIT] The Southern California Association of Marine Invertebrate Taxonomists. (2008). A taxonomic listing of soft bottom macro- and megabenthic invertebrates from infaunal and epibenthic monitoring programs in the Southern California Bight; Edition 5. SCAMIT. San Pedro, CA.

Warwick, R.M. (1993). Environmental impact studies on marine communities: pragmatical considerations. Australian Journal Ecology 18: 63–80.

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